

DETERMINATION OF COMFORTABLE SAFE WIDTH IN AN EXCLUSIVE MOTORCYCLE LANE

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Abstract: Motorcyclists contributed almost 60% of the fatal accidents in Malaysia. One of the effective engineering approaches to tackle this problem is by segregating these vulnerable road users from other motorized traffic through the provision of an exclusive motorcycle lane. At present there are no specific standards that are available to assess design criteria of exclusive motorcycle lanes. However, it is important to specify optimum control width for exclusive motorcycle lanes to ensure that the design of exclusive motorcycle lane is safe for all motorcycle riders. The estimation of safe control motorcycle lane width was based on a logistic regression. The dependent variable is status with respect to rider comfortable level in overtaking maneuver. The resulting analysis was used to suggest a safe control width of pavement for a straight section of an exclusive motorcycle lane. Result indicates that the safe control width of exclusive motorcycle lane should be 3.81 meters.

Key Words: Exclusive Motorcycle Lane, Safe Distance, Logistic Regression

1. INTRODUCTION

Motorcycle safety constitutes an increasingly significant concern in Malaysia. Radin study (1996) show that motorcyclists contributed more than 60% of the injuries sustained and almost 60% of the fatal accidents that occurred on Malaysian roads. Many policies aiming to drastically reduce the number of motorcycle accidents have been implemented. The situation has improved in the past 6 years (Law and Radin, 2005), many efforts remain to be made. One of the effective engineering approaches to tackle this problem is by segregating these vulnerable road users from other motorized traffic through the provision of an exclusive motorcycle lane or a non exclusive lane that is restricted to motorcyclists with physical barriers and markings.

The positive impact of this provisional motorcycle lane has been proven along an extension of track between the Subang International Airport to the towns of Shah Alam and Klang. There was a significant reduction of 39% in motorcycle accidents following the opening of the lane (Radin *et al.*, 1995). This is also further support, by another study. (Radin and Barton, 1997) which showed that the benefit to cost ratio of providing an exclusive motorcycle lane width ranging from 3.3 m to 5.2 m is about three times depending on the assumptions used in calculation of accident costs and pavement design life of the exclusive lane. Since the benefit higher than the

cost, it has been deduced that the provision of an exclusive motorcycle lane is highly cost effective in resolving motorcycle related accidents and incidents in countries with a high motorcycle population.

At present there are no specific design criteria of exclusive and inclusive motorcycle lanes in Malaysia. Available standards or precedents as they are known for motorcycle track design are “A Guide on Geometric Design of Roads 8/16” and “A Guide to the Design of Cycle Track 10/86” both published by the Public Works Department, Malaysia (PWD, 1986b). Both of these guides cover the design requirement element for an exclusive track. However, some of the design parameters are combinations of basic design requirements of a bicycle track, and a highway, which is not suitable for motorcycle lane.

However, it is important to specify standards for both exclusive and inclusive motorcycle lanes as the optimum control width should be comfortable for all riders. A motorcycle lane, if too wide, will have an impact on the economics of the design. Furthermore it will encourage encroachment of bigger vehicles into the lane and endanger the motorcyclist. If the motorcycle lane is too narrow it will cause discomfort to the rider and probably lead to a higher risk of collision while overtaking. It is also likely cause for obstruction to on going motorcyclists.

Hence, this study attempts to have a preliminary determination of a safe control width at 85th percentile operation speed for an exclusive motorcycle lane in Malaysia

1.1 Type of Motorcycle Lane Facilities

There are three types of motorcycle lane facilities available in Malaysia. The detail of each facility will be discussed in the next section.

1.1.1 Exclusive motorcycle lane

This type of motorcycle lane is a complete separate right-of-way established for the sole use of motorcyclists. This motorcycle lane separates motorcyclists from other motorist and normally has a wide right –of –way. It is not developed from an existing carriageway of a wide road. Such lane helps in reducing conflicts at crossing an intersection with the provision of underpasses and other related facilities. The width of an exclusive motorcycle lane is normally in the range of 2.0m to 3.5m. Plate 1 shows an exclusive motorcycle lane.

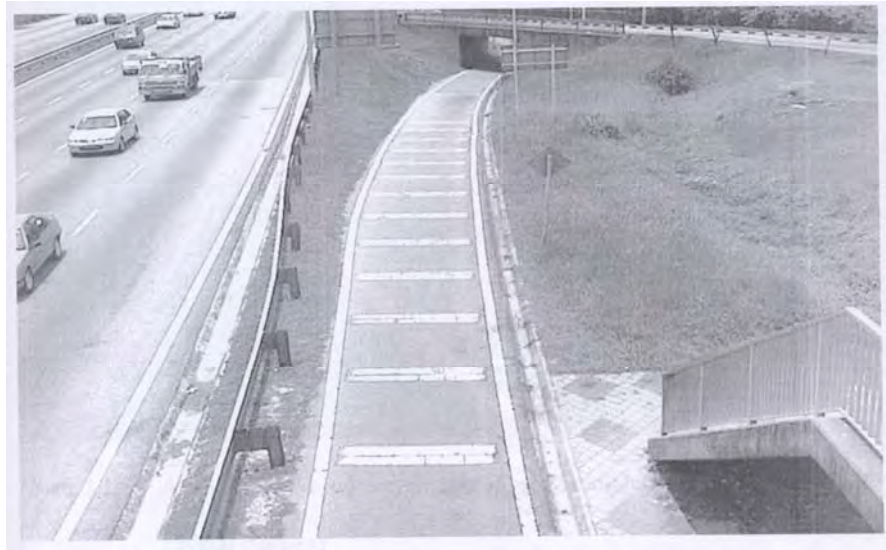


Plate 1. An Exclusive Motorcycle Lane along Federal Highway Route 2

1.1.2 Inclusive motorcycle lane

Inclusive motorcycle lane is popular in Malaysia road. It is developed within the carriageway of an existing road and usually sited on the left side of the road. Some form of physical barrier or pavement marking define the corridor that is set aside for motorcyclists and route marking are necessary to define the route and reduce potential conflicts. However, at crossings and intersections, this kind of motorcycle lane ceases as an exclusive lane and conflicts may occur with other modes of transport. Plate 2 shows an inclusive restricted motorcycle lane.



Plate 2. A Non Exclusive Motorcycle Lane

Another type of non exclusive motorcycle lane is a paved shoulder which does not have designated pavement marking and barrier. This lane provides space for motorcyclists but they have to share the space with other motor vehicles. Plate 3 shows an extended paved shoulder catering for motorcyclists.



Plate 3. Paved Shoulder Road at the Newly Completed Shah Alam Batu Arang Trunk Road

2. METHODOLOGY

2.1 Study Area

The first step in this study is to determine a suitable location along the Federal Highway, Route 2, where the exclusive motorcycle lane is located. The final location was selected based on a lane width of within 2.0 m to 3.7 m, roadway conditions such as geometrical factors, road furniture and existence of a straight road section of least 100 m in length to enable riders to overtake confidently. At the same time, the sample collected had to be well distributed to give a true representation of riders. Plate 4 and 5 provide a close up of the study area from various angles. The motorcycle traffic operating speed was measured during peak hour (7.30 am to 8.30 am) and non peak hour (10.00 am to 11.00am). The 85th percentile operating speed during peak hour and non peak hour is 72 km/h and 80 km/h respectively (Figure 1 and 2).



Plate 4. Road Condition at Study Area Showing Position of Guardrail and Gutter Drain

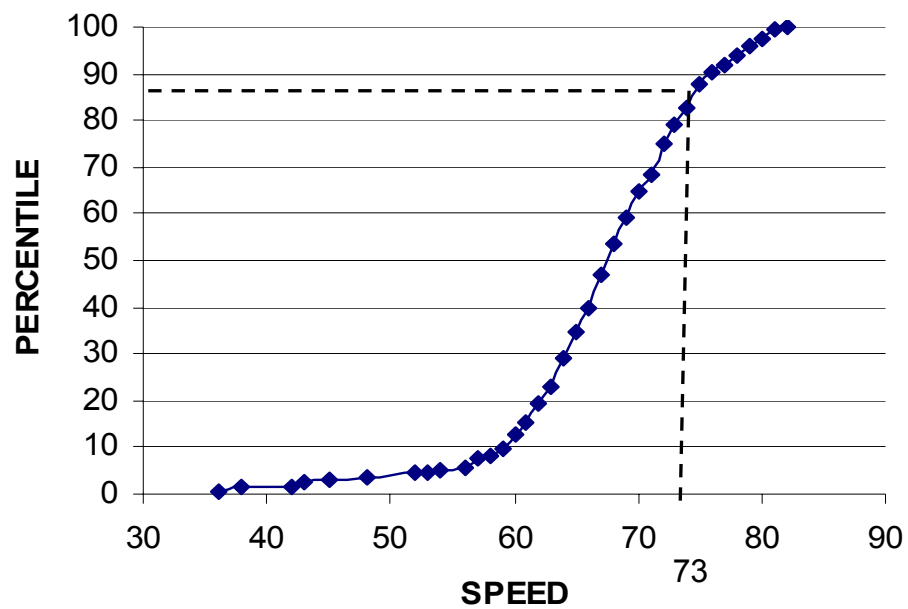


Figure 1. Motorcycle Traffic Operating Speed in Motorcycle Lane during Peak Hour

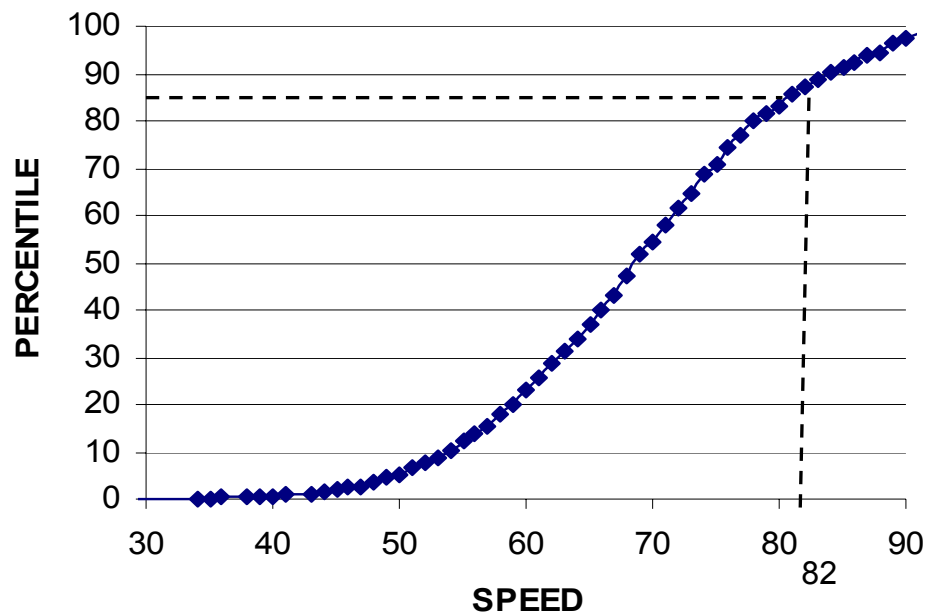


Figure2. Motorcycle Traffic Operating Speed in Motorcycle Lane during Non Peak Hour



Plate 5. A View of Approaching Vehicles to Study Area

2.2 Data Collection

In general, the major task was to videotape motorcyclists to collect necessary data and assess safe distance measurements. The physical characteristics of the road were also recorded during data collection as a supplement to the study. Information on road markings such as marginal stripes, road furniture and other facilities along the road was collected and finally a model of the existing cross section of the road was drawn up. Plate 6 shows recorded distances at the study area.

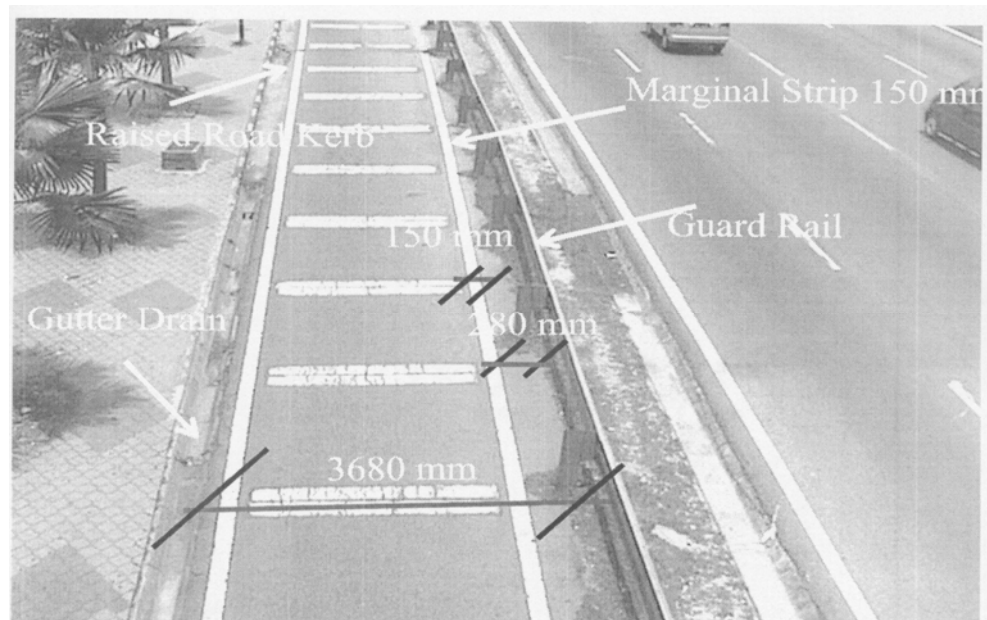


Plate 6. Physical Characteristics of Selected Site

The equipments required for the study were digital camera and S-VHS camera. The S-VHS camera was set up at a pedestrian bridge which is about 6m in height from the carriageway. This section of the road is known as focus point or control point. The focus point is about 25m in length. Once the control point is confirmed, marking with paint proceed for future reference. The focus point cannot be more than 25m because the researcher will experience difficulty in dictating lane change or maneuver while a focus point of less than 25m will reduce substantially the amount of data sample collection when recorded data played.

2.3 Data Processing

Analysis of the data divided into two sections. The first was classification and the second was justification through Logistic regression analysis. The necessary equipments for classification were a VCR player, a 14 inch TV monitor, scale ruler, colored strings and data reduction form. The colored strings are pasted on the TV monitor, starting with the marginal stripes on the left and right motorcycle lane, before further dividing into smaller sections. This section, by separation of colored strings enables detection of even very minor movements of the riders such as lane changing, interaction of riders and measuring safe distance as per Figure 3.

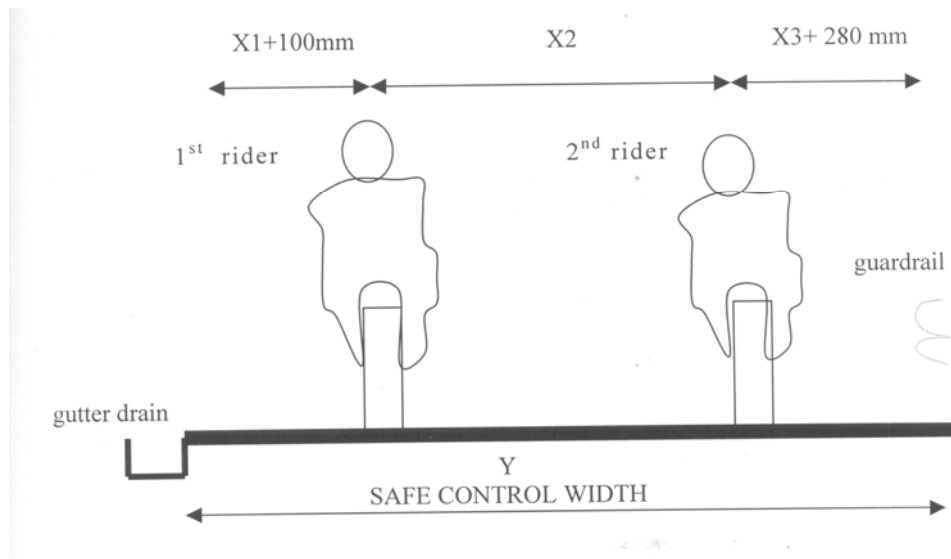


Figure 3. Method of Attaining Effective Safe Distance

The main part of classification is to watch closely the passing maneuver of a motorcyclist and classify as 'Yes' if there is no change of riding in any direction based on the color string separation sections. If the rider on any occasion slow down the motorcycle, changes direction to avoid a passing rider, applies brakes or stops the motorcycle completely to avoid a crash, it will be classified as 'No'. The counting starts after the passing maneuver take place. The sample will be classified 'Yes' if found to be comfortable and 'No' if not comfortable. Table 1 shows the method which were employed to cater for the dichotomous variables as classified in this study.

Table 1. Explanatory Variables for Modeling a Comfortable Safe Distance

| Variables | Description | Coding |
|---------------------------------|--|--|
| Distance to drain (x_1) | Distance from center of nearest rider (first rider) to left marginal strip | 0 – Not Comfortable 1 – Comfortable |
| Safe Distance (x_2) | Distance center to center of riders while overtaking | 0 – Not Comfortable 1 – Comfortable |
| Distance to guardrail (x_3) | Distance from center of nearest rider (second rider) to right marginal strip | 0 – Not Comfortable 1 – Comfortable |

2.4 Data Analysis

The prediction of the second rider is comfortable overtaking was based on a logistic regression of binary response. Logistic regression is a special case of multiple regression in which the

dependent variable is discrete, that is, it can have only two possible values: 0 and 1. In order to calculate the values of the co-efficient, a binomial error distribution and a logit link function were used. In the present study, the dependent variable is assumed to be either comfortable overtaking (value 1) or non-comfortable overtaking (value 0). The predicted probability is expressed by the following equations (Hosmer and Lemeshow, 1989):

$$P(y = 1 / x) = \frac{\exp(\sum \beta_i x_i)}{1 + \exp(\sum \beta_i x_i)} \quad (1)$$

where $P(y=1/x)$ is the estimated probability that second motorcycle rider is comfortable overtaking, \exp the base of the natural logarithm, x_1 , x_2 and x_3 the independent variables, α the intercept parameter estimate, and β_1 , β_2 and β_3 the model slope parameters estimated from the data. The best fitting model was selected using Akaike's information criterion (AIC; Akaike, 1971). On top of this, the success of the correct classification of rider overtaking comfort-ability was seen as the most important criterion for the quality of the model. The estimated comfortable probabilities can be compared with a pre-defined threshold value, for example 0.6. If the comfortable probability is greater than the threshold value, the stem cross section classified "comfortable", otherwise the stem cross section was assigned to the "non-comfortable" group. The classification test was carried out on the basic of those observations, which were used to estimate the parameters of the model.

3. RESULTS

The result of logistic regression analysis is shown in Table 2 to 4. According to comparison of AIC, the logistic regression with the lowest AIC value was selected. In order to classify the stem cross sections by means of the obtained logistic regression a classification threshold value had to be chosen. When a threshold value of 0.65 was used more than 90% of the observations, which served to estimate the parameters, could be assigned to the right group. The relative classification error rate for X_1 , X_2 and X_3 was only 6%, 8% and 5% respectively (Table 5 - 7).

Table 2. Parameters of Safe Distance X_1 of Logistic Regression

| Safe Distance | Coefficient | Standard Error |
|---------------|-------------|----------------|
| Intercept | -2.97 | 0.159 |
| X_1 | 3.98 | 0.165 |

AIC = 51.532, $p < 0.05$

Table 3. Parameters of Safe Distance X_2 of Logistic Regression

| Safe Distance | Coefficient | Standard Error |
|---------------|-------------|----------------|
| Intercept | -2.54 | 0.171 |
| X_2 | 3.02 | 0.089 |

AIC = 43.131, $p < 0.05$

Table 4. Parameters of Safe Distance X_3 of Logistic Regression

| Safe Distance | Coefficient | Standard Error |
|---------------|-------------|----------------|
| Intercept | -2.75 | 0.151 |
| X_3 | 3.76 | 0.144 |

AIC = 46.362, $p < 0.05$

Table 5. Overall Predictability for Safe Distance from Gutter Drain Section to Center Rider (X_1)

| Observed | | Predicted | | |
|------------------------------|-----|-------------|-----|------------|
| | | Comfortable | | Error Rate |
| | | Yes | No | |
| Safe distance between riders | | | | |
| Comfortable | Yes | 212 | 15 | 4% |
| | No | 6 | 117 | 2% |
| Overall Error Rate | | | | 6% |

Overall Correct Percentage = 94%

Table 6. Overall Predictability for Safe Distance between Riders (X_2)

| Observed | | Predicted | | Error Rate |
|------------------------------|-----|-------------|-----|------------|
| | | Comfortable | | |
| | | Yes | No | |
| Safe distance between riders | | | | |
| Comfortable | Yes | 210 | 17 | 5% |
| | No | 11 | 112 | 3% |
| Overall Error Rate | | | | 8% |

Overall Correct Percentage = 92%

Table 7. Overall Predictability for Safe Distance from Guardrail to Center of Rider (X_3)

| Table 4. Confusion Matrix for Safe Distance from Obstacles (23) | | | | |
|---|-----|-------------|-----|------------|
| | | Predicted | | |
| | | Comfortable | | Error Rate |
| | | Yes | No | |
| Safe distance between riders | | | | |
| Comfortable | Yes | 215 | 13 | 3.7% |
| | No | 5 | 117 | 1.3% |
| Overall Error Rate | | | | 5% |
| Overall Correct Percentage = 95% | | | | |

3.1 Interpretation of Results

The relationship between the probability of the second rider comfortable overtaking and safe distances are shown in Figure 4–6. Based on the 85 percentile safe distance of 3.81 meters is recommended to dual motorcycle lane at mean operating speed of 70 km/h. The safe distance from gutter drain section to center rider (X_1) is 1.19 meter. The safe distance based on center to rider (X_2) and the distance from guardrail to center of rider (X_3) is 1.44 meters and 1.18 meters respectively.

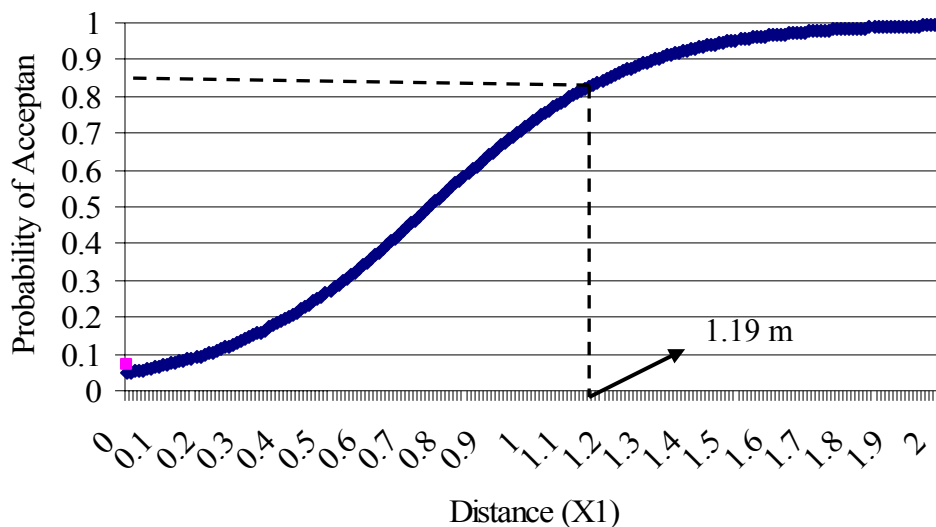


Figure 4. Relationship between the Probability of Rider Comfortable Overtaking and the Safe Distance (X_1)

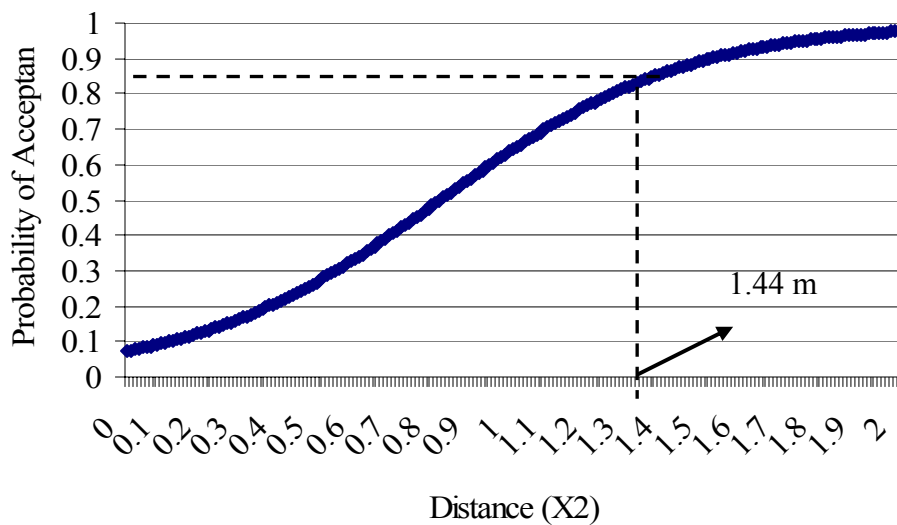


Figure 5. Relationship between the Probability of Rider Comfortable Overtaking and the Safe Distance (X₂)

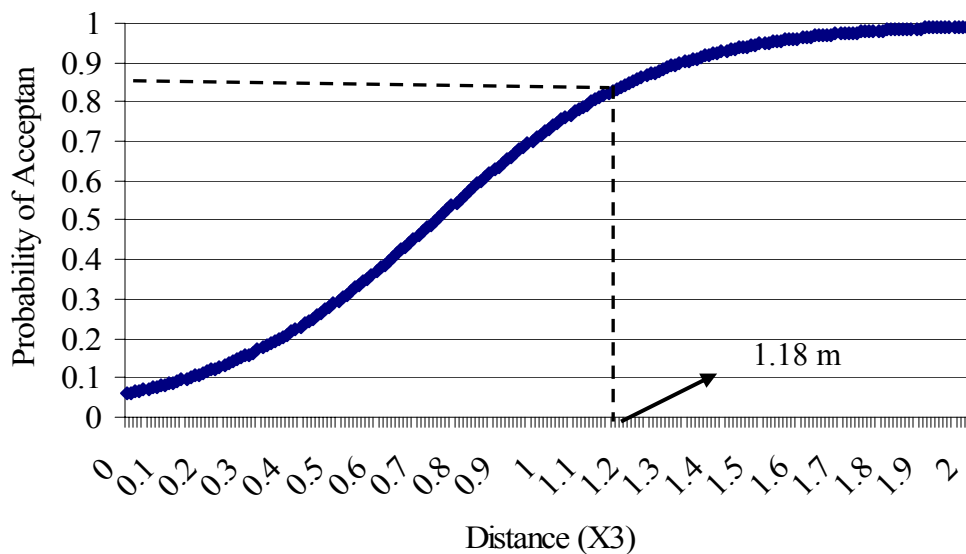


Figure 6. Relationship between the Probability of Rider Comfortable Overtaking and the Safe Distance (X₃)

4. DISCUSSION

Based on a study by Harkey et al. (1996), it can be summarized that the safe distance between motor vehicle and bicyclist is in the range of 1.80 meters and 1.95 meters while bicyclist is to roadway edge is in the range of 0.43 meter to 0.80 meters regardless of the facilities. This is a clear indication that the finding of this study are likely to be in the acceptable zone since the safe

distance between riders is 1.44 meters while distance of riders to edge of pavement is in the range of 1.18 to 1.19 meters as found in Harkey's study.

The contributing factors to the slight change in the value expected compared to the above study can be attributed to the operational speed, the standard size of tire, environmental effects and type of facilities. This study found that an exclusive motorcycle lane needs a control width of 3.81 meters (inclusive of marginal stripe 0.38 meter at both edge of road) for two riders to travel side by side comfortably at a speed of 70 km/h. Certainly Ministry of Work's adoption of 3.5 meters is lower than recommended safe desirable distance value based on 85 percentile probability. Plate 7 shows the detailed design of pavement width.

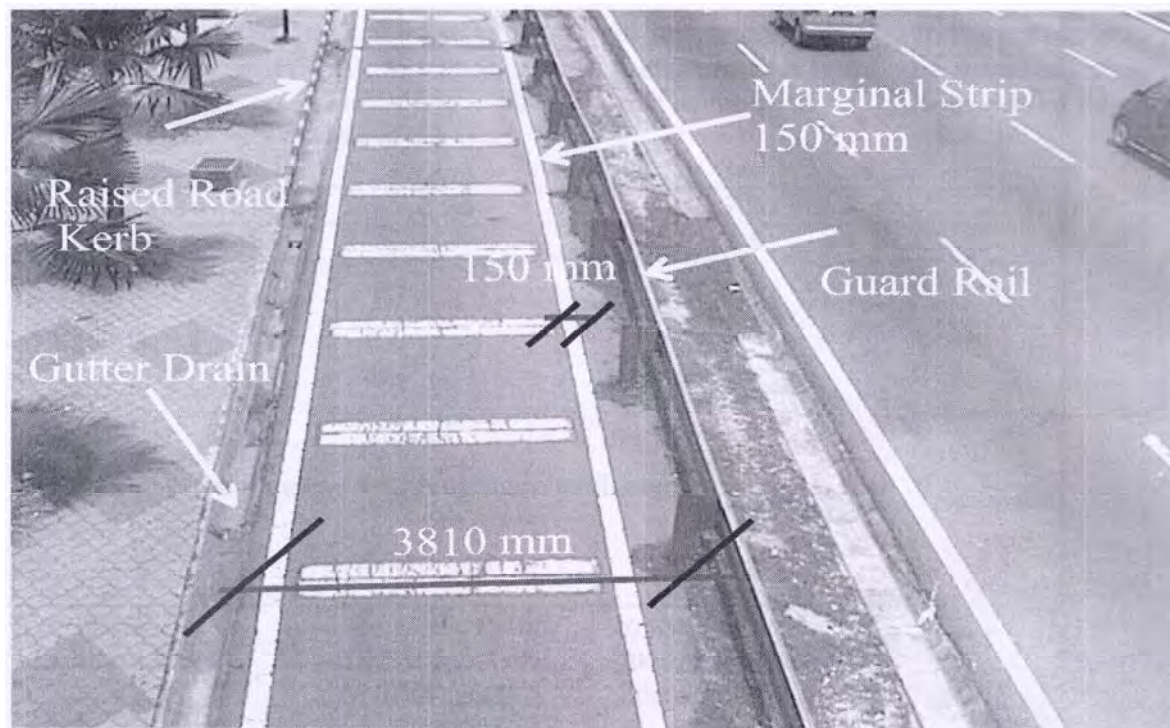


Plate 7. Recommended Control Width for an Exclusive Motorcycle Lane

5. CONCLUSION

Based on the discussion and recommendation, it can be concluded that the study has contributed towards optimizing operating conditions for motorcyclists, while simultaneously minimizing requirements for pave surface and right-of-way rules. However, it should be noted that this recommended comfortable control width are based on interactions between motorcyclists at a straight section of the roadway.

Therefore, the researcher concludes with an earnest request that the findings of this study be seriously considered by policy makers in the design of exclusive motorcycle lanes as the safe control width suggested is economical, comfortable to riders and is envisaged to reduce the number of accidents among this vulnerable group of road users.

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